APPENDIX D
FORECAST GUIDANCE

These suggestions for predicting certain conditions and characteristics of the winter shamal are largely "rules of thumb" culled by the author of this technical report from two years of experience as a meteorologist/forecaster in the Persian Gulf region. They represent, in large part, a distillation of the experience of forecaster colleagues in the Gulf. In two cases, however -- item (4), Para. D.1.1; and Para. D.2 -- the indicated procedures were suggested by research for this report and thus may require further tuning based on actual field experience.

D.1 RULE 1: ONSET

D.1.1 Midwinter - Mid-December through February

Although it is difficult to forecast with precision the time of a shamal's onset, favorable indications from any of the considerations listed below point to an onset. If all are favorable, occurrence over the entire Gulf is indicated.

(1) A cold upper-air long-wave trough with central temperature of at least -25°C at 500 mb, dips south of the Taurus Mountains of Turkey. This trough is often associated with a blocking high pressure ridge over central or eastern Europe; the ridge forces cold air south over the eastern Mediterranean-Lebanon-Syria area to "dig" the trough south of the Taurus Mountains and bring in the cold air.

(2) The long wave upper air trough tends to "hang back" over the eastern Mediterranean (see main text, Para. 3.3.4, and Figures 5a-e). From mid-December through February, the shorter waves that may move eastward from the long wave position (Para. 3.3.4) do not tend to produce the cyclogenesis in the lower Tigris-Euphrates valley/northern Gulf region which precedes most winter shamals. The movement eastward of the long wave trough itself, however, tends to produce this cyclogenesis. Thus, make the best possible prognosis of when the long wave trough will move eastward. Ignore the shorter waves which may move eastward from the long wave position.

(3) Plot consecutive Skew-T Log-P diagrams from station 40650 (Baghdad, Iraq), 40831 (Abadan, Iran), or 40372 (Kuwait); station locations are shown in Figure D-1. Analyze these plots for Lifting Condensation Level (LCL),

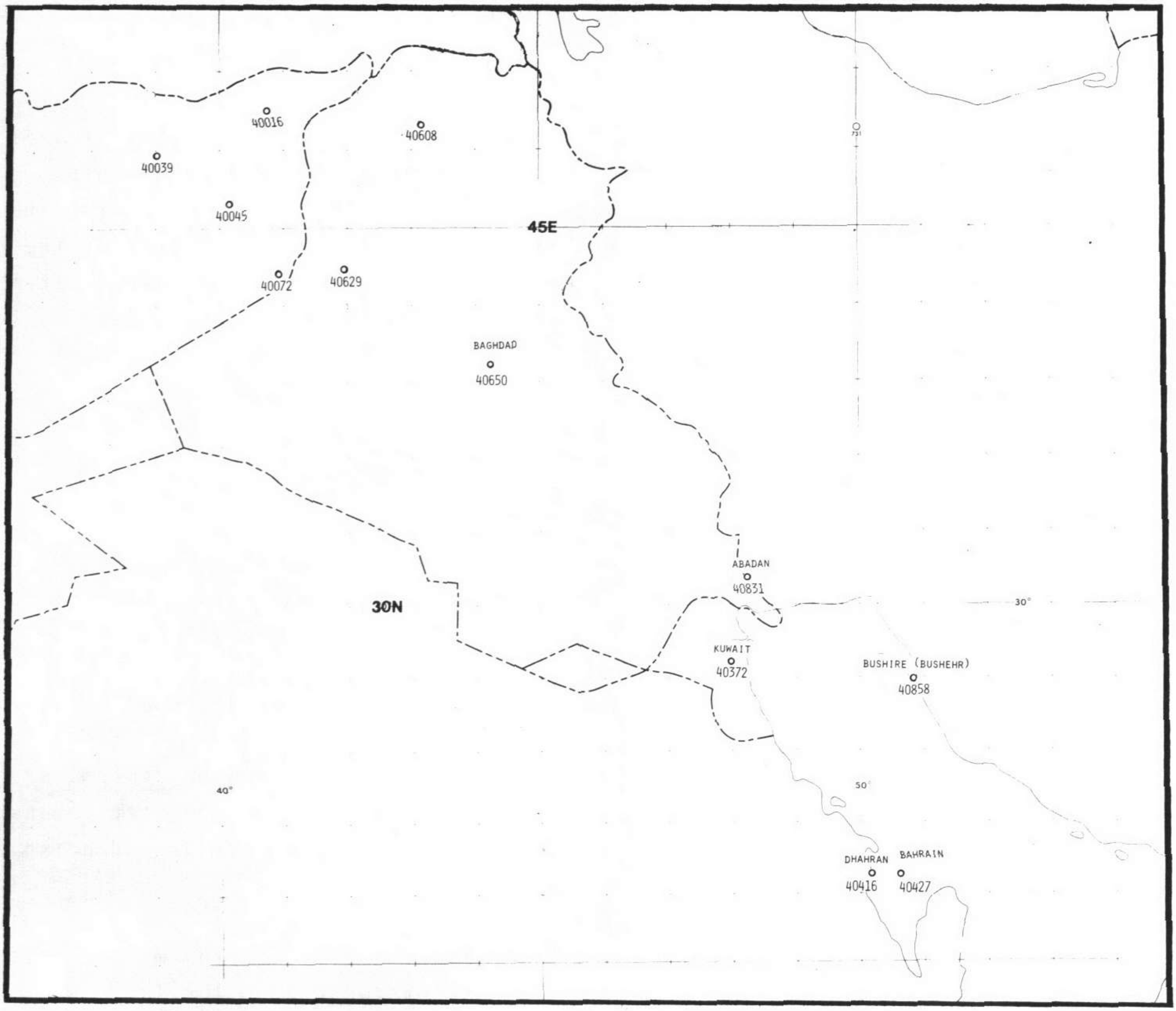

Figure D-1. Locations of stations referenced in text Para. D.1.1 (3).

Convective Condensation Level (CCL), and Level of Free Convection (LFC).* The Skew-T Log-P diagrams should be conditionally unstable (i.e., an LFC should exist) from 12 hr to 24 hr before onset of the shamal. Use the LCL to determine the LFC, as the air is to be orographically lifted (AWSM 105-124, pp 4-14). The conditional instability should increase somewhat on consecutive Skew-T Log-P diagrams as onset time approaches (i.e., the "positive energy area" above LFC should increase on successive Skew T's). Fig. D-2 shows a typical radiosonde ascent for Baghdad for 12Z 23 Jan 1974, with analyses of the LCL, LFC, and positive and negative energy areas.

(4) The average surface temperature contrast between stations in the upper Euphrates Valley and stations surrounding the northern and central Gulf should equal or exceed 12°C, during the period from mid-December through February. This surface temperature contrast should be determined by averaging daytime (12Z) and nighttime (00Z) surface temperatures to compensate for the effects of daytime heating and nocturnal cooling of the air in the lowest layers of the troposphere.

Obtain the required average surface temperatures by following these steps:

(a) Select from among the following groups a set of surface stations at 12Z to represent surface temperature reports from the upper Euphrates valley: 40016, 40039, 40045, 40072 in Syria; 40608 and 40629 in northern Iraq. Note that surface reports from stations in the Middle East are available somewhat sporadically, so use as many stations from those given above as are available.

From the stations selected, average the surface temperatures together to form $T_{U_{12Z}}$

(b) Select a set of surface stations from 12Z from among the following to represent reports from the northern and central Gulf: 40372, 40831, 40858, 40416, and 40427. Again, use as many of these stations as are available.

From the stations selected, average the surface temperatures together to form $T_{G_{12Z}}$. (Note the locations of the stations given in (a) and (b) above may be found in Figure D-1.)

(c) Repeat step (a), using surface data from 00Z, to form $T_{U_{00Z}}$.

(d) Repeat step (b), using surface data from 00Z, to form $T_{G_{00Z}}$.

*See NAVEDTRA 10363-E, Aerographer's Mate 3 and 2 Rate Training Manual, pp. 236-238; NAVEDTRA 10362-B, Aerographer's Mate 1 and C Rate Training Manual, pp. 52-55; or AWSM 105-24/NAVAIR 50-1P-5, Use of Skew T, Log-P Diagram in Analysis and Forecasting, pp. 4-13, 14, 15, for determination of these quantities.

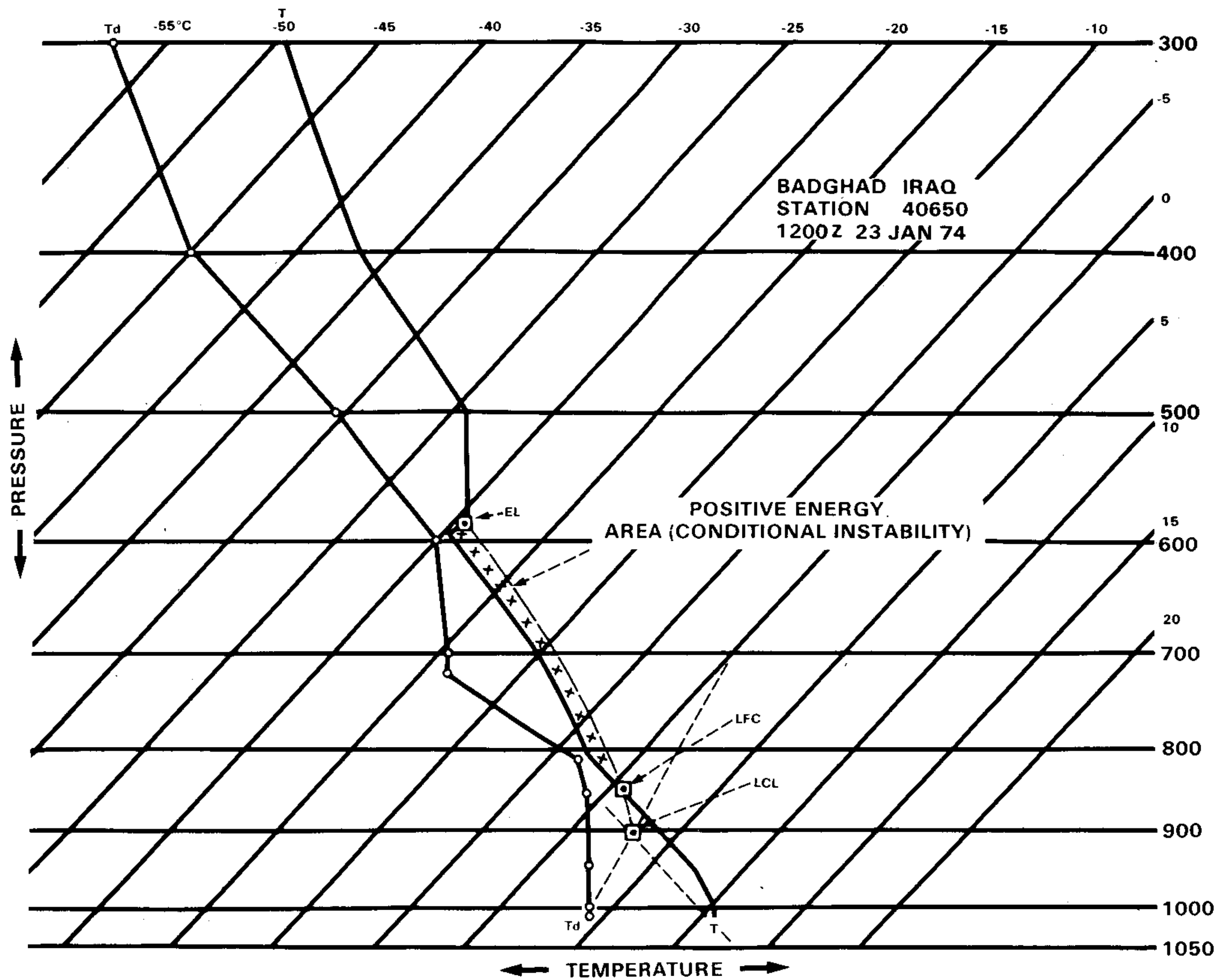

Figure D-2. Typical pre-shamal Skew-T Log-P diagram.

(e) Average the values for both regions over time, to compensate for daytime heating and nocturnal cooling of the air:

$$T_U = \frac{T_{U_{12Z}} + T_{U_{00Z}}}{2}$$

$$T_G = \frac{T_{G_{12Z}} + T_{G_{00Z}}}{2}$$

(f) The required temperature contrast thus becomes

$$T_G - T_U,$$

and $$T_G - T_U \geq 12°C\ .$$

(5) From the prognoses of the upper air, determine when the long wave upper trough axis will lie just north of the Gulf. Since the shamal begins before the trough axis reaches this point, forecast the time of the onset of the shamal to coincide with the time when the upper trough axis is at the midway point (approximately 44°E) between the upper Euphrates valley (the Syria/Iraq border, longitude 41°E) and a position just north of the Gulf (longitude 48°E).

D.1.2 <u>Late Fall - November through mid-December</u>

Use the same rules as above, relaxing the surface temperature contrast and central 500 mb temperature criteria slightly. Forecast the shamal over the northern Gulf only.

D.2 RULE 2: ONSET INTENSITY (NOV-FEB)

(1) Use area average temperatures derived in Rule 1. Use the formula

$$C = 1/2\sqrt{gh\frac{\Delta T}{\bar{T}}}$$

where C is the average wind speed in m/sec; g, acceleration due to gravity, is 9.8 m/sec^2; h is 2500 meters, the typical depth of the cold air mass; ΔT, in °C, equals the difference between the temperatures at the upper Euphrates valley and the northern Gulf; and $\bar{T}$ (°C) is average of the two temperatures.

In computing form for onset wind speed, using the quantities derived for rule D.1.1 (4):

$$C \text{ (in kt)} \approx 156 \times \sqrt{\frac{T_G - T_U}{\frac{T_U + T_G}{2} + 273.16}}$$

where T_U is the average temperature (°C) in the upper Euphrates valley and T_G is the average temperature (°C) of the middle and northern Gulf area.

(2) Add 10 kt to the quantity C, derived in rule 2 (1), for average gusts.

(3) Add 15-20 kt to the quantity, C, derived in rule 2 (1) for peak gusts.

(4) The formula is based on conversion of potential energy in adjacent cold and warm air masses into kinetic energy as the cold air mass underruns the warm air.*

D.3 RULE 3: DURATION (NOV-FEB)

(1) If the upper air prog series (24, 36, 72 hr) and the forecaster's judgment indicate rapid movement of the long wave upper trough through the region without stalling over or near the Strait of Hormuz (in the vicinity of 26.5°N, 56.5°E), forecast 24-36 hr duration for the shamal from the time of onset.**

(2) If the upper air prog series and the forecaster's judgment indicate that the long wave upper trough will stall either over or near the Strait of Hormuz, or else move through the Persian Gulf region very slowly, forecast the shamal to last 3 to 5 days. Recheck the prog series every 12 hr to confirm the forecast, recalling that the 3-5 day extended shamal is a rare event.

(3) If the shamal is expected to last more than 2 days, forecast wind speeds of 35-45 kt in the southern Gulf, where the surface pressure gradient will be strongest.

D.4 RULE 4: CESSATION

This rule of thumb is for the 3-5 day shamal, which occurs from mid-December through February.

Check the upper air prog series and determine when the upper trough will move away to the east. Forecast the shamal to break by sunset of the day on which the trough moves away. If satellite images are available, they should be examined to see whether a convergence band off Oman is present in late morning images (see Case Studies 1 and 2, Appendices A and B respectively, Figures A-31, A-32, B-30 and B-35). If the convergence band is present,

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*After Margules, suggested by Feteris (1973), and cited on p. 301 in Hess (1959).

**If the forecaster is using Fleet Numerical Weather Central (FNWC) prognoses, he should be aware that the FNWC upper air progs are pure persistence from the equator to about 10°N, that they are fully pronostic north of about 20°N, and that they are a blend of the two between 10°N and 20°N. As the southern part of the Persian Gulf lies north of 22.5°N latitude, the forecaster can be generally confident that the FNWC progs are fully prognostic in Gulf regions; this is the region, however, that borders the latitude where the progs begin to blend from prognostic to persistence.

forecast the shamal to end that evening. Forecast northwest winds 15-20 kt in the western Gulf that afternoon. Forecast local sea breezes, southeasterlies, or a combination in the eastern Gulf.

D.5 RULE 5: TYPICAL SEA HEIGHTS (NOV-FEB)

The sea heights given here are the significant heights, i.e., the average of the highest one-third observed.

When the cool shamal winds blow over the warm, shallow Persian Gulf, they raise a short-period, steep sea faster and higher than would a wind of similar strength over the open sea.

(1) If the initial wind forecast is for 30-40 kt, forecast:

(a) Combined sea height to rise to 10-12 ft, 12-24 hr after onset.

(b) Combined sea height to rise further 12-14 ft, 24-36 hr after onset, if the shamal persists that long.

(2) If the shamal persists for more than 36 hr, a rare event, increase wind forecast to 35 to 45 kt in the southern Gulf and increase combined sea heights in the southern Gulf to a maximum of 15-18 ft.

D.6 RULE 6: LATE-SEASON SPECIAL CASES

This rule of thumb addresses shamals that occasionally occur in late winter and into early spring. Sea heights (significant) given are the average of the highest one-third observed.

(1) In March, forecast 12-24 hr 30 kt northwesterlies with each vigorous 500 mb short wave passage (see Section 3.2*). Forecast maximum combined sea height of 10-12 ft. Forecast the residual swell decay according to Rule 7 below.

(2) During the first half of April, the same rule applies, but limit the wind to 25-30 kt and forecast for the northern Gulf only. Forecast a maximum combined sea height of 8-10 ft. Forecast the residual swell decay according to Rule 7.

D.7 RULE 7: SWELL DECAY

(1) For the day following the break of 24-36 hr shamal:

(a) Forecast 2-4 ft swell if the maximum significant combined sea height was 10-12 ft during the shamal.

(b) Adjust this forecast upward or downward if higher or lower maximum significant combined sea heights occurred during the shamal.

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*This is an exception to the guidance of Para. D.1.1 (2). In this situation the short waves are significant and should not be ignored.

(2) Following the break in the 3-5 day shamal, if 12-15 ft maximum significant combined seas occurred:

(a) Forecast 6-8 ft swell on the day after the shamal breaks.

(b) Forecast 3-5 ft swell on the second day after the shamal breaks.

(c) Forecast 1-3 ft swell on the third day after the shamal breaks.

D.8 RULE 8: HIGHER-WINDS SPECIAL CASES

These modifications to previous guidance should be applied for those areas that experience higher than normal winds during shamal occurrences. See discussion in main text, Para. 3.6.1, and Figure 3-7.

(1) For the area east of the Qatar Peninsula:

(a) Add 10-15 ft to wind speeds determined by rules 2, 3, or 5.

(b) Add 2-4 ft to all combined sea or residual swell heights determined by rule 6.

(c) Add an extra day of significant residual swell (2-4 ft significant swell height).

(2) For the area near Lavan Island, but only in March and early April:

(a) Add 10 kt to wind speed determined by rule 5.

(b) Add 2-4 ft to combined sea heights determined by rule 5 or residual swell determined by rule 6.

(c) Add an extra day of significant residual swell (2-4 ft significant swell height).

D.9 RULE 9: THUNDERSTORMS, RAINSHOWERS

(1) Thunderstorms and rainshowers in conjunction with the shamal are more frequent in the northern Gulf than in the south.

(2) Subsidence in the lower troposphere behind cold fronts can quickly suppress convection behind the front.

(3) Include thunderstorms and rainshowers with each forecast of shamal onset for the northern Gulf. Forecast convective activity to precede cold frontal passage and onset of the shamal by 3-6 hr. Forecast the severest thunderstorm activity north of the subtropical jet axis; determine the axis from satellite images or upper air (200 mb) progs, as demonstrated in Case Study 1, Appendix A.

(4) Check satellite images, if available, for evidence of development or suppression of convection after frontal passage and modify the forecast accordingly.

D.10 RULE 10: REDUCED VISIBILITY IN BLOWING DUST

Visibility can be reduced during shamal occurrences, most severely in the northern Gulf area, by wind-blown dust drawn from the arid surface of the lower Tigris-Euphrates valley.

(1) For the first shamal of the season, forecast sharply reduced visibilities of one-eighth to one-quarter of a mile in blowing dust.

(2) Keep a record through the winter season of the interval between rainfalls over the lower Tigris-Euphrates valley region. The longer the interval since the previous rainfall, the more likely the soil surface will become dry and powdery, thus increasing the likelihood of blowing dust during shamals following such dry periods.

D.11 RULE 11: LOW LEVEL TURBULENCE

D.11.1 Prior to the Passage of the Cold Front

(1) If the maximum surface wind speed associated with the Kaus is expected to be at or near gale force, forecast light to moderate turbulence from the surface to 5000 ft in the center of the Gulf (the east-west speed shear zone), and from 3000 ft to 8000 ft over the eastern Gulf (the vertical speed shear zone).

(2) Forecast locally severe turbulence in and near organized convective cells at all levels of the troposphere in and near organized prefrontal lines of convective cells.

D.11.2 In Association with the Cold Front

(1) Forecast moderate to locally severe turbulence in and near convective cells imbedded in the cold front.

D.11.3 After the Cold Front has Passed Through the Gulf Region

(1) Forecast light to moderate turbulence in the lowest 3000-5000 ft of the atmosphere, in association with the gusty strong wind zone which extends from the frontal position back to the northwest.

(2) Use DMSP imagery to pinpoint the more severe occurrences of this sort of low level turbulence. The cloud pattern to look for is that of postfrontal cumulus caused by relatively cold air streaming over warmer Gulf waters. Upgrade the turbulence in these areas to moderate.

(3) Forecast moderate mechanical turbulence to occur in the area on the eastern side of the Gulf in the lee (to the west) of the Zagros Mountains, during the extended 3-5 day shamal.

Forecast the turbulence 1000-2000 ft below the mountain crest height to 3000-5000 ft above it; the general height range of the Zagros Mountains is 6000-9000 ft. A conservative estimate of the altitudes for the turbulence would be 4000-11000 ft for mountain heights of approximately 6000 ft, and 7000-14000 ft for mountain heights of approximately 9000 ft.

(4) Forecast moderate to severe turbulence in the region downstream of mountainous areas which produce wave clouds. Forecasting an altitude for the turbulence is difficult because it is a function of local stability and other local effects such as the specific wind speed and direction, specific terrain configuration and vertical wind profile. A conservative estimate would be at least 2000-3000 ft below the crest of the mountains (although mountain wave turbulence can reach the ground) up to a maximum height of jet stream altitudes.

D.12 RULE 12: UPPER LEVEL TURBULENCE

(1) Forecast light to moderate turbulence at altitudes of 20,000-35,000 ft near the subtropical jet when it is present. The normal winter position of the jet is near the middle-to-southern Gulf.

(2) During winter shamal occurrences, broaden the turbulence area to include the region from just south of the subtropical jet to just north of the polar jet. (See Section 3.8, main text, and Figures 3-9 and 3-10.) Note that when the shamal occurs, the subtropical jet tends to be displaced southward by the intrusion of the polar jet south of the Taurus Mountains of Turkey to a position over Iraq, Syria, Iran, and northern Saudi Arabia.

(3) Forecast moderate to severe turbulence at 15,000-30,000 ft in the northern, polar-jet portion of the turbulence region (Figures 3-9, 3-10).

(4) Forecast moderate to severe turbulence at 20,000-35,000 ft in the southern, subtropical-jet portion of the turbulence region (Figures 3-9, 3-10).

(5) More detailed guidance for forecasting upper level turbulence is given in the technical publication NWRF 15-0568-137(II), 1968; Clear-Air Turbulence, Part II, A Survey of Contemporary Prediction Techniques and Recommended Operational Procedure.

(6) Rules D.11.1 (2), D.11.2 (1), and D.11.3 (4) also apply in forecasting regions of upper level turbulence.